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# The growth of snapdragons, stocks, cinerarias and carnations on six Iowa soils

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# THE GROWTH OF SNAPDRAGONS, STOCKS, CINERARIAS AND CARNATIONS ON SIX IOWA SOILS

by

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Signatures have been redacted for privacy



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## INTRODUCTION

At the thirty-sixth annual meeting of the Society of Iowa Florists, held at Des Moines in November, 1938, the chairman of the organization's research committee, Mr. J. F. Wilcox, Jr., Council Bluffs, was called upon to discuss "What Do Iowa Florists Want in the Way of a Research and Extension Program?" Mr. Wilcox thereupon enumerated several projects which he and the committee, comprised of Professor E. C. Volz, head of floriculture at Iowa State College, and Mr. A. A. Bezdek, Cedar Rapids, deemed most important. (4)

From that suggested list of projects, the five most worthy of attention were chosen and submitted to the authorities of the college for consideration. Among the proposed projects was one asking for an investigation of the response of greenhouse crops to various Iowa soil types. This appealed to all concerned as an investigation that should lead to valuable practical and scientific results, and accordingly it was undertaken as Project No. 675 of the Iowa Agricultural Experiment Station. The report embodied herein is an account of the first year's studies of the growth of snapdragons, stocks, cinerarias and carnations on six Iowa soil types, Clarion loam, Webster loam, Clinton silt loam, Knox silt loam, O'Neill loam, Wabash silty clay loam, and a greenhouse compost prepared from the Webster.

White (51), in introducing his discussion on soils for greenhouses, states that "The success or failure of a flower grower depends to a large measure on the physical character of the soil and the chemical elements that it contains." Surely no one can deny that the soil is one of the most important factors in the successful production of greenhouse flowers. That the growers realize that much depends upon their soil and on their understanding of how crops respond to different soils is evidenced by their requesting the undertaking of this project.

Within the last 10 to 12 years investigations at several of the state experiment stations have shown that methods of soilless plant culture may have a definite place in the scheme of commercial flower production. Wagner and Laurie (46) list all of the important greenhouse crops as having been grown successfully in gravel culture.

In spite of the progress which is being made in gravel culture, the majority of florists are still using soil and will continue to use soil for many years to come, since it is impractical for a man with a small or medium sized range to install the expensive mechanical devices required for chemical plant culture. Gravel culture is feasible only in large ranges and for those who specialize in a limited number of crops. In Iowa the largest number of florists have small greenhouses and grow a very wide selection of stock; therefore soil will probably continue to be the most important medium for the culture of their plants.

## REVIEW OF LITERATURE

### Greenhouse Soil Studies

A review of the literature reveals few studies of the growth of greenhouse flower crops on different soils. This is quite in contrast to the very extensive experiments which have been carried on by practically all of the state experiment stations with field crops and, to some extent, vegetable crops.

Pember and Adams (25) studied the influence of physical soil factors on the growth of the carnation by varying the physical condition of the soil on which the plants were growing through the addition of stable manure and other types of organic matter. Little in the way of conclusive recommendations can be derived from that publication, except that they found the addition of stable manure gave a larger production than did the addition of any other material. Volz and Post (44), reporting on a similar investigation, using sweet peas and other greenhouse plants on soil to which different types of organic matter had been added, found that organic materials have a definite effect upon the resulting plant growth but that the effect varies with the species. Pot plants did not respond in the same way as bench crops, nor did legumes behave the same as non-legumes.

Thompson (43) studied different types of muck soils to determine their value in growing both vegetable and flower greenhouse crops. The mucks which he used came from New Jersey, Michigan and Indiana. When these materials were mixed with clay in the ratio of one part muck to two or three parts clay, they gave the largest yields.

To meet the objections to the applicability of soils and fertilizer studies carried out at the various experiment stations on only the local soil type, White in 1935 (52, 53) undertook a cooperative project with eight growers in Massachusetts. Carnation plots were maintained at the growers' ranges and fertilized as directed by the station; thus several soil types were included. Upon the compilation of the data at the end of the first season, it was found that there were no appreciable differences in the number of flowers produced per square foot. It was observed that wherever a grower had high yields on his own plots, the college treatment gave correspondingly high production. Conversely, where production was low on a grower's benches, the college treatment also gave low yields. Therefore, it would seem that some cultural condition within the greenhouse was more greatly concerned with production and quality of flowers than were the fertilizer treatments. Unfortunately the growers did not appear interested in continuing the experiment over a longer period.

In floricultural literature soil recommendations for specific crops are frequently given. For example, Wiggin (55) writes that carnations seem to grow best on a medium loam with an abundance of humus and that he believes that carnations prefer a porous rather open soil. He carefully adds in connection with these statements, however, that there are no figures available to support them. Laurie and Poesch (24) likewise state that a strong sandy loam of porous structure and with a good organic matter content provides the most satisfactory soil for carnations, but then they go on to say, "However, experimental data have shown that the plants may be grown successfully in gravel or cinders without any organic matter but with sufficient nutritive additions."

In introducing a series of articles on the principles of handling greenhouse soils, Post (27) has made statements which may be summarized briefly as follows: General rules cannot be made to govern the fertilizing of all plants under varying soil conditions. Most growers devise a particular way of their own for preparing and treating their soil. Two or more growers may have the same or a similar type of soil to work with, yet they may treat it entirely differently and still arrive at the same or very similar results.

Beattie (7) has written to the effect that each man's soil problem is distinct and is influenced by soil, temperature, moisture supply and other factors.

## Soil Types

Iowa is situated in a soil province where the major surface deposits have originated primarily either from deposition by ice or from deposition by wind. Associated with these deposits there is material which has been laid down by the streams along their banks in recent times or in the more or less distant past. These alluvial deposits are known as first bottomlands in the first case and as terraces in the second.

It is convenient to classify the soils dealt with in this study into three groups on the basis of the conditions attendant upon their development, i.e., prairie soils, gray-brown podzol soils and alluvial soils. A description of those three groups and the six soil types used in this study follows: (3, 9)

## Prairie soils

The typical prairie soils have developed in cool, moderately humid climates under the influence of grass vegetation. These soils occur in the Middlewest and occupy a large part of the Corn Belt. The profiles are characterized by dark brown to nearly black, mildly acid surface soils underlaid by brown well-oxidized subsoils. The parent materials have a wide range in composition. This group includes soils which rank among the best in the United States in the production of corn and oats.

Clarion loam. Clarion soils are characterized by a dark brown to black surface. The soils are of Wisconsin drift origin and have been modified relatively little by weathering and leaching. The type has good natural drainage, a high productivity rating and under good systems of management can be depended upon for satisfactory crops.

The Clarion loam is one of the most extensively developed soils in the state. It occurs in large individual areas in the more rolling, naturally better-drained uplands in the central and north central part of Iowa. It is mostly all under cultivation, is highly productive, and hence is one of the most valuable soils of the state.

Webster loam. Soils of the Webster series are black. They occur on nearly level to undulating drift plains where no erosion has taken place. They have been formed by weathering in position of drift material under poor drainage conditions.

Webster loam is an important upland drift soil type, being mapped in extensive areas on the more nearly level uplands in the Wisconsin drift soil area. The topography is level to slightly undulating. This soil is mostly cultivated and when well drained, crop yields are excellent. It is one of the highest soils of the state in natural productivity.

## Gray-brown podzol soils

Gray-brown podzol soils of the eastern and midwestern part of the United States are developed under deciduous forest and in a humid temperate climate. Typical members of this soil group have a thin leaf litter lying on an inch or two of dark grayish-brown humus, which in turn grades into a grayish-brown leached horizon which extends to a depth of 8 or 10 inches. The productivity of the gray-brown podzol soils varies considerably. Their reaction is usually medium acid. In general they are much lower in nitrogen and organic matter than the prairie and alluvial soils associated with them.

Clinton silt loam. Soils of this series are characterized by a gray or dark gray surface horizon. The series is derived by weathering from loess and in Iowa is typically developed in the loess belt west of the Mississippi River, north of Missouri.

The Clinton silt loam is one of the most important upland soil types in the state. It occurs in many individually large areas of the loessial uplands in the Mississippi loess soil area and in southern Iowa.

The topography varies from undulating to gently rolling. The type is cultivated in many counties, while in some it is largely in timber and timber and pasture. It is extremely variable in productivity, depending on its position and the system of soil management which has been practiced.

Knox silt loam. The Knox series consists of light colored calcareous soils derived by weathering from loess. The soils are brown in color; surface drainage is good.

Knox silt loam is an important upland soil, being mapped in considerable areas in western Iowa in the Missouri loess soil area. In topography the type is rolling to rough or steep and broken. It is partly cultivated in most of the counties where it is mapped.

## Alluvial soils

Alluvial soils occur in all parts of the United States, on flood plains, first bottoms, or low terraces along streams. The alluvial soils of the prairie are developed from sediments derived by erosion from the dark colored upland soils. Except where drainage is very poor, these soils retain many of the characteristics of the parent materials. The most widely distributed soils are those of the Wabash series.

O'Neill loam. Soils of the O'Neill series consist essentially of dark gray to dark brown or nearly black soils, underlaid by light brown subsoils resting upon a substratum of sand and gravel. The series occupies high terraces along river and stream beds. It is derived by weathering from glacial outwash or terrace material.

O'Neill loam is one of the most important terrace or second bottomland soils in Iowa. It is found along the streams in many sections. The topography is very gently sloping to level and it varies from a few to many feet above the bottomlands. It is mostly cultivated; crop yields are good in favorable seasons and under good systems of management.

Wabash silty clay loam. The Wabash series includes soils of dark brown to black color with a high organic matter content. The series is developed in the first bottomland along streams, principally from loessial and silty glacial soils. It is subject to overflow but natural drainage is well established in some areas.

Wabash silty clay loam is an important first bottomland soil type. It is mapped along streams in all parts of the state. In topography the soil is level to flat or depressed. It is mostly in pasture or wild hay, although it is largely cultivated in some counties.

## MATERIALS AND METHODS

### Choice of Soils and Crops

At the start of this project the immediate problem confronting the investigator dealt with the selection of soil types and the plants to be used in the first year's work.

A survey of the areas under glass in Iowa (45) shows them to be concentrated in certain regions. In order to make the soils tie in as closely as possible with those which the growers are using, all samples brought to Ames were representative of soils being used by some growers in an important greenhouse area. In choosing the soils consideration was given also to the origin of the leading soil groups of the state, and an attempt was made to include one or two types from each such group. These soil groups and types have already been mentioned and discussed. A greenhouse compost prepared from the Webster according to commercial practice was included as a check.

Realizing that the growth which a plant makes on a soil depends to a great extent on the characteristics of the individual species and that only a limited number of plants could be included, four were chosen which exhibit different habits of growth and different commercial methods of handling. They were snapdragon, *Antirrhinum majus*, Linn.; stock, *Matthiola* *incana*, R. Br.; cineraria, *Cineraria cruenta*, Mass.; and carnation, *Dianthus Caryophyllus*, Linn.

In the past two decades no cutflower has risen in popularity with such amazing speed as the snapdragon. The ease with which it can be grown from seed and marketed during any month of the year accounts for this phenomenal rise. Today, among greenhouse cutflowers, it is fourth in order of commercial importance. As an annual it lent itself very well to the opening season's work. Unfortunately the snapdragons were injured by illuminating gas which escaped from a leaking main about 20 feet east of the house in which the plants were grown, and it was deemed advisable to repeat the study using some fast-growing annual. Accordingly stocks, which have of late become a very popular winter and early spring cutflower, were chosen. They are one of the most profitable of the minor crops grown by florists.

The cineraria was included as a representative of a commercial potted plant. It is an excellent flowering plant for sale from January to May.

The carnation is one of the oldest flowers under cultivation and is the second leading commercial cutflower in the United States. These facts are due to the lasting quality and fragrance of the flowers and the continued yield during a period of the year when there is a demand for flowers. Carnations are also an extremely important florist crop in Iowa, and it was in order to make the study more closely applicable to the industry in the state that the carnation was included. Since this project had not been planned early in the year, there were not enough plants available to set up a properly designed test with sufficient plot replications and they were used as an indicator for future work and not as a principal crop during the first year.

## Soil Treatments

The soils which were used in this study were brought to the college in two-cubic-yard quantities during August, 1939. They were secured as follows:

Clarion loam
Kemble-Smith Co., Inc.
Boone, Boone County, Iowa

Clinton silt loam
H. G. Pauli & Sons
Davenport, Scott County, Iowa

Knox silt loam
J. F. Wilcox & Sons, Inc.
Council Bluffs, Pottawattamie County, Iowa

O'Neill loam
Sherman Nursery Co.
Charles City, Floyd County, Iowa

Wabash silty clay loam
Midwest Floral Company
Marshalltown, Marshall County, Iowa

Webster loam
Iowa State College Horticultural Farm

Greenhouse compost
Iowa State College Horticultural Farm

The soil referred to as greenhouse compost is prepared by piling alternate layers of a Webster sod with manure in the proportion of 3:1. After a year of decomposition this mixture is run through a soil shredder and used for greenhouse work.

Hereafter all soils will be referred to by using only the series name, except the compost which will be called compost.

Preparatory to planting, the soils were thoroughly mixed with commercial fertilizers at the following rate:

| | | | | |
|---|---|---|---|---|
| Ammonium sulfate . . . . . | 200 | lbs. | per | acre |
| Muriate of potash . . . . | 300 | " | " | " |
| Superphosphate 20% . . . . | 750 | " | " | " |

All of the soils were weighed and samples were taken for moisture determinations. Two million pounds, dry weight, were considered equivalent to the acre furrow slice. To insure thorough mixing, the soils, with the fertilizers added, were passed through a 1/2-inch mesh screen in addition to being turned six times on a concrete floor.

In supplementary fertilization during the growing periods ammonium sulfate was applied in solution at the rates given in the discussions on the specific crops. These rates were based on crop response and on soil nitrate tests, using the phenoldisulphonic acid method (18).

Total nitrogen determinations were made by the Kjeldahl method. Soil reaction tests were by the Truog Soil Reaction Tester for rapid pH determinations.

## Crop Culture

### Snapdragon

On August 5 seed of snapdragon var. Cheviot Maid Supreme was sown in a shallow flat in a mixture of equal parts of compost, leafmold and sand. The seedlings were transplanted into 2-inch pots in composted soil on August 25. It was assumed that the small volume of foreign soil introduced with the seedlings at the time of benching would not interfere seriously with the comparative nature of the study. Furthermore, it is a common practice among growers to use a specially prepared soil for seedlings and a soil different from that of the permanent location.

Diagram 1 and the illustration on page 20 show the design of the bench plots used for the snapdragons. Each plot was $2\frac{1}{2}$ x 4 feet. The bench was the center one of greenhouse No. 14 of the horticulture range. All of the soils were prepared as previously described before they were placed in the bench. To allow for a proper analysis of the data, the soils were arranged in randomized blocks with three replications. The replications and soil distribution in the plots are also indicated in diagram 1.

The seedlings were benched directly from 2-inch pots on September 20 at a distance of 8 x 9 inches. There were 18 plants per plot. By selecting from a large number of plants

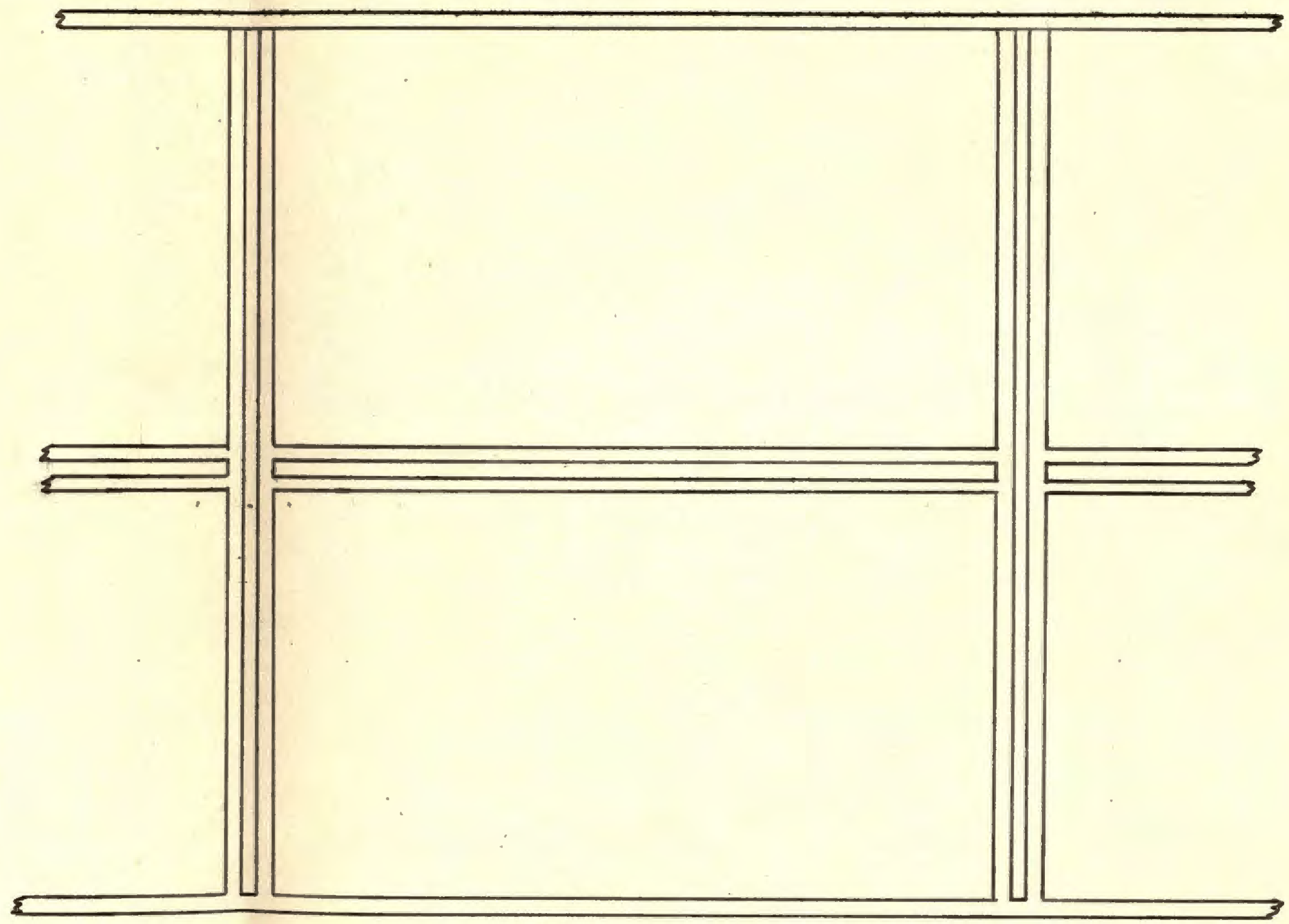
DIAGRAM 1. SNAPDRAGON BENCH SHOWING ARRANGEMENT OF SOILS AND DETAIL OF PLOT CONSTRUCTION

| | Replication 1 | | | | Replication 2 | | | | Replication 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| b | 3 | 7 | 1 | 4 | 2 | 6 | a | 5 | 7 | 4 | 5 | b |
| | 2 | 6 | 5 | 3 | 7 | 4 | 1 | 3 | 2 | 6 | 1 | |

Key to Plots

1. Compost
2. Knox
3. Clarion
4. Wabash
5. Clinton
6. Webster
7. O'Neill

a. extra plot
b. buffer plot



Detail of Plot Construction

Scale: 1" = 1'

Fig. 1. Snapdragon bench, showing design of plots.

a uniform lot was secured. After the plants became established and had grown for two weeks they were pinched above the third node to induce branching.

Studies at the North Carolina station (2), to determine the effects of pinching on snapdragon, showed that it pays to pinch and that one pinch is better than two. Post (30) carried this work further by determining the effects of pinching at various heights and times. Extremely early or late pinching relative to the time of benching reduced production. Pinching above the third or fourth node gave the greatest stem length and the best quality of flower.

Other methods of handling were much the same as are used in commercial practice. Night temperature was maintained at as near 50°F. as possible. The plants were supported by wires and strings stretched lengthwise and crosswise of the bench respectively. Little disbudding was practiced.

Water was applied copiously when the plants showed a need for it. Laurie and Mann (23), studying the water needs of several greenhouse crops, found that where 10, 20, 30 and 40 gallons of water were applied weekly to 84-square-foot plots, the stem length of snapdragons increased as the water increased. Heavy applications of water at infrequent intervals, thus allowing the soil to dry out partially, have proven more satisfactory than lighter applications at frequent intervals.

In early December, when flower buds became visible, all of the plants except those on the compost began to show nitrogen deficiency symptoms. Tests for soil nitrates revealed about 100 ppm were present in the compost soil and less than 10 ppm in each of the others. Ammonium sulfate equivalent to 50 ppm of soil nitrates was added on December 9 to all the uncomposted soils. Within four to five days after fertilization the plants which had previously shown nitrogen deficiency symptoms began to take on a darker green color. Supplementary nitrogen fertilization was given again in February at the same rate as in December.

Data on the snapdragons consist of individual plant records of the number of flower spikes and of stem length. Spikes were cut above the third node from the point of branching when eight individual florets were open. Only one crop of flowers was removed. Time of bloom was also recorded. No measure of flower quality was secured because of the gas injury. Post (30) writes regarding the snapdragon, "It is difficult to measure quality, but length of stem has been found to correlate fairly well with length of flower head and size and strength of stem."

## Stock

Seed of column or non-branching stock var. Lilac Lavender was sown in a light soil mixture in flats in a 60°F. greenhouse on February 26. Twelve hundred of the most vigorous seedlings were potted into 2-inch pots in a soil prepared for the seedlings on March 16 and set again in a 60°F. greenhouse.

The crop of stocks was grown in the same bench and soil that had been used for the snapdragons. The snapdragon plants, including the larger roots, were removed on the last of March. The mass of fibrous roots remaining in the soil after the removal of the snapdragons, however, was quite appreciable. Just before planting the stocks, fertilizers were worked into the soils by mixing them in place in the bench. The rate of fertilization used at that time was as follows:

| | | |
|---|---|---|
| Ammonium sulfate . . . . . | 200 | lbs. per acre |
| Muriate of potash . . . . | 150 | " " " |
| Superphosphate 20% . . . . | 375 | " " " |

The stock seedlings were benched April 5 at a distance of 6 x 6 inches. There were 35 plants per plot. This allowed for a further rigid selection of the plants from the large number which had been potted.

About mid-May, after the flower buds were visible and a rapid elongation had taken place, nitrogen deficiency symptoms appeared. On the basis of soil nitrate tests ammonium sulfate was added to the O'Neill, Knox and Wabash soils on May 4 and to the Clarion, Clinton and Webster soils 10 days later at the same rate as given above.

Stocks are rather unique in that there are two distinct types, the single- and the double-flowered. The latter contain no anthers or pistils and produce no seed. Growers of stocks are interested almost exclusively in the double forms, since the singles are practically worthless on the market. For that reason records were maintained separately on the two types.

Flower spikes were considered ready for cutting when 10 individual flowers were completely open. The total height of each plant was measured from the ground and the total number of "flowers plus buds" was recorded. Date of cutting was also tabulated.

Cineraria

Cineraria seed, var. Cremer's Prize, was sown on September 8 in a flat in a soil mixture similar to that used for the snapdragons. One month later the seedlings were potted in compost in 2½-inch pots and grown at 60°F. November 21 the seedlings were selected for uniformity and divided into 15 groups of 7 and were shifted into 4-inch pots using the various soil types. After this shift they were placed on the west bench of greenhouse No. 1 in randomized blocks of seven. Each block contained one pot of each soil. The replications were set up in rows parallel to the length of the bench.

Greenhouse No. 1 was maintained as a cool house at 50°F. night temperature. Post (32) writes that high temperature delays flowering of cinerarias and prevents it in some cases. He found that the earlier the plants were shifted to low temperature, the sooner they flowered.

To reduce variation due to bench position, all of the blocks were rotated every two weeks. As the plants increased in size they were also given a greater spacing. By December 25 root action had become quite vigorous and the plants were shifted to $5\frac{1}{2}$-inch pots in which they were finished. Fortnightly block rotations continued until the first plants in full bloom were removed.

Growth was rapid following the last shift and by mid-January it was evident that supplementary nitrogen fertilization would become necessary. Each pot was given 150 cc. of ammonium sulfate solution (1 pound per 30 gallons of water) at 10-day intervals during the next two months.

Frequent foliage syringing with water served in controlling thrips and red spider, which are often injurious to this crop.

Once a week all the plants which had reached a commercially salable condition were taken from the bench and judged independently by three judges on a score card basis. Professor E. C. Volz, Mr. Wm. Jeffrey and the writer were the judges. Because the regular score card used in judging flowering potted plants considers such points as flower color, a genetic variable, and rarity, also not applicable here, the following modified form was used:

| | |
|---|---|
| Cultural perfection . . . | 30 |
| Floriferousness . . . . . | 20 |
| Size . . . . . . . . . . . | 20 |
| Form . . . . . . . . . . . | 15 |
| Foliage . . . . . . . . . . | 15 |

In the analysis and data presented the average of the three scores was used as a measure of the quality of the plant.

After judging, all of the above ground parts of the plants were removed and dried in a constant temperature chamber at 76-77°C. and the dry weights of each determined.

Carnation

The plants used in this experiment were propagated during the winter of 1939. The rooted cuttings were potted in $2\frac{1}{2}$-inch pots in greenhouse compost and carried in that until April, when they went into the field for the summer months.

Diagram 2 shows the plot arrangement. Each plot was $3\frac{1}{2}$ x 5 feet. The bench area used was the center section of the middle bench of greenhouse No. 1. This was the same house in which the cinerarias were grown.

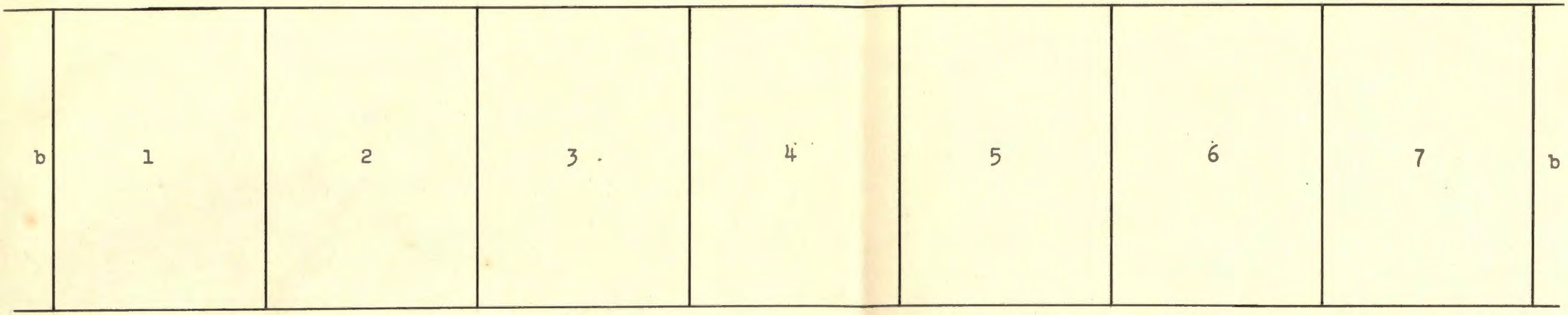
After the available plants had been selected for uniformity there were so few that it was necessary to employ three varieties. The first two rows in each plot were planted with var. Red Spectrum, the third row with var. Chief Kokomo, and the fourth row with var. King Cardinal. There were six plants per row, making a total of 24 per plot.

While the carnations were growing in the field they had been pinched frequently to induce branching. All of the plants when they were benched on August 18 had 12-15 shoots. The planting distance was approximately 10 x 10 inches. Pinching was continued until September 15.

To control carnation rust, sulfur dust and 4-6-50 bordeaux sprays were used during the fall. Red spider was controlled by syringing forcefully with water.

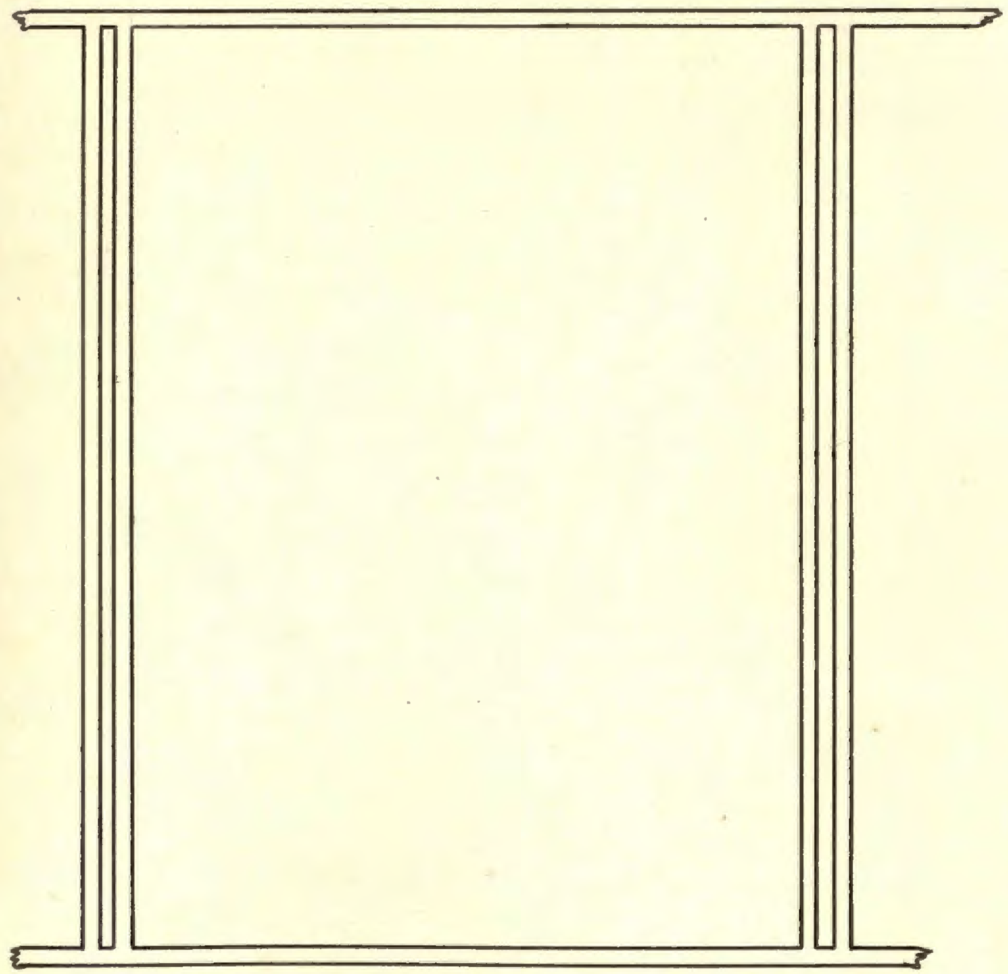
During the first few weeks after benching, some of the plants of var. Red Spectrum died from dry stem rot. The dead

DIAGRAM 2. CARNATION BENCH SHOWING ARRANGEMENT OF SOILS AND DETAIL OF BENCH CONSTRUCTION




<u>Key to Plots</u>

1. Clarion
2. Knox
3. O'Neill
4. Wabash
5. Clinton
6. Webster
7. Compost
b. buffer



Detail of Plot Construction

Scale: 1" = 1'

plants were replaced by others from the field.

In early December, when flowering was well under way, soil samples were taken from each plot and water soluble nitrates determined. The tests revealed all of the soils except the compost were below 10 ppm; the compost had about 50 ppm. Ammonium sulfate was added on December 9 to bring the nitrate level of all the soils to that of the compost. Similar tests in February resulted in the addition of ammonium sulfate to all the plots to raise them to the 50 ppm level. The compost at that time had dropped to 20 ppm of nitrates.

About the time that flowering began it was found that the plants of var. Red Spectrum were infested with root nematodes. Therefore, no records were kept on the plants of that variety. By spring the infestation had spread to the adjoining rows of each plot so that no records were considered on var. Chief Kokomo after March 1.

Records were kept by plants; measurements were made of both stem length and flower diameter. The flowers were cut from October, when production began, until Mother's Day, May 12. This is the most important period of commercial cutting. Harvesting was handled as it would be in actual practice. The flowers were removed by cutting the stem betweem the first and second tier of wire-string support as they reached the proper stage.

Data were also kept on the number of flowers with split calyces. Each flower on which the calyx was split three-fourths of its length was regarded as a "split."

The florists' carnations occur in three genetically distinct forms: the single, the double, and the superdouble or bullhead (17). The bullheads are so extremely double that the calyces split badly as the flowers expand and are worthless. Even among the commercial varieties, which are all of the double type, the condition known as splitting is a problem and has received much study. Work at the New Jersey station (8) has shown that splitting is influenced by both hereditary and environmental factors. More recently, Szendel (41, 42) investigated the effects of temperature and nutrition on calyx splitting. He found that more splitting occurred with the more frequent fertilizer applications, but the increase in splitting was not proportional to the increase in the total number of flowers cut or to the increase in the total amount of fertilizer added. The percentage of split calyces was also found to increase as the temperature was reduced. Short low temperature periods, occurring at great time intervals, also increased splitting.

# RESULTS AND DISCUSSION

## Crops

### Snapdragon

Table 1 presents the average number of snapdragon flower stems per plant. Analysis of the data (table 2) shows that the average number of stems does not differ significantly when grown on these soils. Probably this could be anticipated, because the height of pinching or the number of nodes remaining determines approximately the number of shoots which arise; all these plants were pinched leaving the same number of nodes.

In table 3 the soils are listed in order, beginning with the one producing the greatest mean stem length. The range of means is 6.2, a highly significant difference which may be important in a high-class flower market where the longer stemmed flowers command a fancy price. On local and smaller markets, such as those on which these flowers were disposed, nearly all the stems are shortened before sale and there is no advantage to the longer ones except that they may have larger flower heads.

The behavior of this crop on the various soils was quite interesting, especially because the compost gave the shortest mean stem length. Through the entire period of growth, the

Table 1. Snapdragons - Average Number of Flower Stems per Plant

| Soil | Replication 1 | Replication 2 | Replication 3 | Means |
|---|---|---|---|---|
| O'Neill | 4.22 | 3.94 | 4.06 | 4.07 |
| Knox | 4.11 | 4.06 | 3.72 | 3.96 |
| Clarion | 3.89 | 3.78 | 4.17 | 3.94 |
| Compost | 3.78 | 3.94 | 4.06 | 3.93 |
| Wabash | 4.00 | 3.28 | 3.83 | 3.70 |
| Webster | 4.06 | 3.56 | 3.50 | 3.70 |
| Clinton | 3.67 | 3.67 | 3.72 | 3.69 |
| Replication means | 3.96 | 3.75 | 3.87 | |

Least mean difference for significance: .05 1.63
.01 2.29

Table 2. Snapdragons - Analysis of Variance of Number of Flower Stems per Plant

| Source of Variation | Degrees of Freedom | Mean Square |
|---|---|---|
| Soils | 6 | 1.33 |
| Replications | 2 | 1.45 |
| Experimental error | 12 | .84 |
| Sampling error | 357 | 1.17 |

The test of significance of differences in number of flower stems:

$$F = 1.33/.84 = 1.58$$

Table 3. Snapdragons - Average Stem Length (inches)

| Soil | Replication 1 | Replication 2 | Replication 3 | Means |
|---|---|---|---|---|
| Wabash | 38.2 | 37.8 | 31.9 | 35.9 |
| Knox | 35.7 | 35.9 | 33.1 | 34.9 |
| O'Neill | 36.0 | 34.2 | 31.2 | 33.8 |
| Clarion | 32.7 | 32.3 | 31.5 | 32.2 |
| Webster | 32.5 | 31.1 | 29.7 | 31.1 |
| Clinton | 32.1 | 29.7 | 29.1 | 30.3 |
| Compost | 31.8 | 28.0 | 29.2 | 29.7 |
| Replication means | 34.1 | 32.7 | 30.8 | |

Least mean difference for significance: .05 3.03
.01 4.25

Table 4. Snapdragons - Analysis of Variance of Stem Length

| Source of Variation | Degrees of Freedom | Mean Square |
|---|---|---|
| Soils | 6 | 309.43 |
| Replications | 2 | 353.83 |
| Experimental error | 12 | 28.98 |
| Sampling error | 357 | 25.58 |

The test of significance of differences in stem length:

$$F = 309.43/28.98 = 10.68$$

plants on the compost plots were more dwarf. This may be explained by the high concentration of nitrates which was present in the soil during the fall and early winter; it may have been so high as to retard growth.

Post and Bell (35), studying the effects of excess fertilizers while growing the plants in sand, found an excess of sodium nitrate caused larger leaves with necrotic areas within the blade. At New Jersey (1) snapdragons grown in solutions of low, rather than high, osmotic concentration made the better growth. It may be that this plant is easily injured by concentrations of soluble salts.

The regression in average stem length from replicate one to replicate three is worth noting and explaining. The bench which was used extended east and west in a greenhouse of the same directions. The east gable of that greenhouse was exposed, while the west end abutted another house; for that reason a temperature gradient existed in the house. Thermographs were set up at both ends of the bench and records showed differences up to 10°F. This temperature variation accounts for the regression in stem length. The time of flowering was also influenced by the temperature, as is evidenced by the fact that half of the flowers in replication three were cut by March 1, in replication two by March 6, and in replication one by March 18. This agrees with the findings of Weddle (47), who, in order to determine the effect of various air temperatures on snapdragon growth, grew them at three night temperatures.

Plants grown at 50°F. bloomed April 4, at 55°F. March 28, and at 60°F. March 12. He also found that the largest and most vigorous stems were produced at the lowest temperature.

All of the snapdragons were cut between January 3 and March 31.

Gas injuries. Mention has already been made of the gas injury which occurred in the greenhouse where the snapdragons were growing. In September and October gas injury symptoms were noticed in the main conservatory of the college range. Bougainvilleas and Crotons dropped their leaves; flowers and buds abscissed on the allamandas. Those are typical responses for those species.

In February peculiar abnormalities became very apparent in the snapdragon house. At that time there was a very wide variety of plants in the house and it provided an excellent opportunity for taking notes on gas injury to various crops.

That the cause of the injury was illuminating gas is proven by the typical epinastic response of young vigorously growing tomato seedlings (11) which were placed in the house, and the fact that nearly all crops recovered promptly after a gas main east of the range had been replaced.

Gas injury to plants is not new or uncommon. Crocker and Knight (12) state that as early as 1864 observations were recorded on the effect of illuminating gas on vegetation. In spite of long recognition of damage from such a source, injury still very frequently occurs in greenhouse ranges (21).

Doubt (14) has reported on the responses of a great many plants to illuminating gas, describing carefully the typical injury expression. Crocker, Zimmerman and Hitchcock (13) report studies conducted with 202 different species and varieties, determining their response to ethylene. The same authors (59) summarize the responses of plants subjected to illuminating gases as (1) epinastic growth, (2) abscission of leaves, buds, flowers and fruits, (3) killing of buds, (4) stimulation of buds to premature opening, and (5) color changes.

Besides ethylene, other gases which may and frequently do cause injury in greenhouses are sulfur dioxide (57) and vapors of mercury and mercury compounds (58).

Illustrated on pages 36 and 37 are gas injured and healthy specimens of stock and snapdragon. The typical response observed on stocks was a failure of the flower buds to develop. On snapdragons the florets dropped before they were completely open and the leaves showed a peculiar type of longitudinal curling. After the gas leak was repaired the snapdragons returned to complete normalcy.

Other plants growing in the house and showing typical injuries were: Schizanthus, leaf epinasty; ornamental leaved begonias, leaf abscission; cacti and succulents, branch and leaf abscission; and Myosotis, longitudinal curling of the leaves, similar to snapdragon, and a darkening of the green of the foliage.

Fig. 2. Top: Stocks, showing gas injury symptoms.
Bottom: Stocks, normal.

Fig. 3. Top: Snapdragons, showing gas injury symptoms.
Bottom: Snapdragons, normal.

Stock

Data on the stem length and number of "flowers plus buds" of 724 plants of stock are summarized in tables 5 and 7. From the analyses of variance (tables 6 and 8) it is seen that neither the differences in height nor those in the number of "flowers plus buds" are significant. The regression in the average number of "flowers plus buds" per replication going from east to west on the bench (that is, in the direction of increasing temperature), although not statistically significant, is interesting for it may indicate a trend which is real.

During the last decade studies of environmental factors and plant growth have shown that temperature is an important factor in bud differentiation and flowering of stocks. Post (29), growing stocks at various temperatures, found that no plants differentiated flower buds when the temperature was maintained above 60°F. This failure to form buds is frequently known as blindness and is to be associated with the biennial reaction of stocks grown under conditions of high temperature. Further studies (31) have shown that a 14-day treatment at 50-60°F. was sufficient for some plants to form buds, while 21 days at that temperature was sufficient for all of the plants to form buds if the plants were of sufficient size. An increase in temperature after a low temperature period of 21 or more days hastened flowering. Many interesting observations on the effect of alternating temperatures on the flowering

Table 5. Stocks - Average Number of "Flowers plus Buds" per Plant

| Soil | Replication 1 | Replication 2 | Replication 3 | Means |
|---|---|---|---|---|
| Knox | 27.9 | 25.4 | 28.4 | 27.2 |
| O'Neill | 30.7 | 22.5 | 23.1 | 25.4 |
| Clinton | 25.8 | 24.4 | 25.3 | 25.2 |
| Clarion | 26.7 | 26.2 | 21.5 | 24.8 |
| Webster | 27.7 | 22.8 | 23.6 | 24.7 |
| Wabash | 24.7 | 23.6 | 24.5 | 24.3 |
| Compost | 25.5 | 23.9 | 20.3 | 23.2 |
| Replication means | 27.4 | 24.1 | 23.8 | |

Table 6. Stocks - Analysis of Variance of the Number of "Flowers plus Buds" per Plant

| Source of Variation | Degrees of Freedom | Mean Square |
|---|---|---|
| Soils | 6 | 150.5 |
| Replications | 2 | 751.5 |
| Experimental error | 12 | 342.5 |
| Sampling error | 703 | 58.5 |

The test of significance of differences in the number of "flowers plus buds":

$$F = 150.5/342.5 = .44$$

Table 7. Stocks - Average Height of Plant (inches)

| Soil | Replication 1 | Replication 2 | Replication 3 | Means |
|---|---|---|---|---|
| Knox | 26.8 | 25.6 | 25.9 | 26.1 |
| Compost | 23.9 | 26.5 | 25.5 | 25.3 |
| O'Neill | 25.6 | 25.7 | 24.5 | 25.2 |
| Clarion | 24.4 | 25.9 | 24.8 | 25.0 |
| Webster | 24.8 | 23.0 | 24.7 | 24.2 |
| Wabash | 24.3 | 24.0 | 24.1 | 24.1 |
| Clinton | 24.2 | 24.3 | 23.7 | 24.1 |
| Replication means | 24.9 | 25.0 | 24.7 | |

Table 8. Stocks - Analysis of Variance of Height of Plants

| Source of Variation | Degrees of Freedom | Mean Square |
|---|---|---|
| Soils | 6 | 60.0 |
| Replications | 2 | 5.0 |
| Experimental error | 12 | 55.1 |
| Sampling error | 703 | 3.55 |

The test of significance of differences in the height of plants:

$$F = 60.0/55.1 = 1.09$$

of lavender column stocks are reported by Post and Bell (34). Emsweller and Borthwick (16), also studying the effects of short periods of low temperature on flower production in stocks, state that in some instances the growing point of column lavender stocks can be changed from a vegetative to a reproductive condition in as short a period as 48 hours.

The additional data presented here would lead to the conclusion that temperature may also influence the total number of buds formed.

For future experimentation it may be valuable to point out that with this variety of stocks plots with 35 plants are perhaps larger than necessary. This conclusion is based on the fact that the sampling error mean square is much smaller than the mean square for experimental error.

On page 42 are photographs of the first four spikes of doubles cut from each of the seven soils. From the pictures it is seen that all of the flowers were of excellent commercial grade. Certain minor differences in foliage and such points as go to make up quality in cutflowers did exist. Definitely poorer than any of the others were those grown on the Wabash soil. The foliage yellowed and the basal leaves withered as the plants on this soil reached the stage for cutting. Plants on the O'Neill were also well below the others in quality. Of highest quality, considering luxuriance of foliage and sturdiness of stems, were those grown on the compost and Knox. It may be that score card evaluation of these flowers would give a better








Fig. 4. Stocks, first four spikes of doubles cut from each soil.

Key to numbers:
1. Webster
2. Compost
3. Clinton
4. O'Neill
5. Wabash
6. Knox
7. Clarion

measure of performance than such indices as height and total number of "flowers plus buds."

Doubleness and singleness in stocks has already been referred to. The occurrence of so-called high double producing strains was for long a point of speculation. Saunders (37) gave the explanation when she wrote that doubles on the whole develop more vigorously and rapidly than the singles and that where the period of development is sufficiently prolonged, selection based on that difference in vigor can be used as a means of securing a higher proportion of doubles than corresponds with the actual output of the parent plants. Only conscious or unconscious selection will cause the per cent of doubles to be over the expected 54-56 (38). These speculations on increasing the percentage of doubles have been substantiated by experimental data from work by Jaramillo and Chittenden (19), Allen (6) and Emsweller (15).

One of the objects of the rigid plant selection practiced in this experiment was to increase the percentage of doubles beyond the expected ratio. Records kept on flower type showed that 65 per cent were doubles and 35 per cent were singles.

Records on the date of cutting bring out something of the uniformity of this lot of plants. All of the flowers were cut in the eleven-day period May 29 to June 8; 90.6 per cent were cut in the six-day period May 31 to June 5.

Records from work by Saunders (39) and Pryor (36) indicate that the double-flowered plants bloom in advance of the singles.

This is not substantiated by the data here, where the singles bloomed, on the average, 97.5 days and the doubles 98.3 days after the seed was sown. The discrepancy may be due to seasonal effects.

Differences between the double- and single-flowered plants in height and number of buds are not of practical significance. In this experiment the mean height of the doubles was 25.17 inches and of the singles 24.31 inches. The double-flowered plants had an average of 25.39 "flowers plus buds," while the single-flowered plants averaged 24.17 "flowers plus buds."

Cineraria

The average score and dry weight of the cinerarias on the several soils are presented in table 9. Three plants died. Regardless which index of performance, score or dry weight, is used, the soils line up in essentially the same order of performance. The analyses of variance in table 10 indicate that there are real and highly significant differences among the score and dry weight means for the soils.

Two weeks before any of the plants were removed for scoring, all of the pots were segregated by treatment for observation. The plants at that time were grown and well budded. It is interesting that they then were placed in the same order as they are on the basis of score and weight. Compost was always much superior to any other soil, while Clinton was definitely the poorest. The mean differences in the score and dry weight

Table 9. Cinerarias - Average Score and Dry Weight (grams)

| Soil | Average Score | Average Dry Weight |
|---|---|---|
| Compost | 84.2 | 35.6 |
| Webster | 80.9 | 26.9 |
| O'Neill | 79.9 | 26.8 |
| Clarion | 79.7 | 27.8 |
| Knox | 79.3 | 27.8 |
| Wabash | 76.1 | 21.3 |
| Clinton | 74.7 | 19.8 |

Least mean difference for significance:

| | Score | Dry Weight |
|---|---|---|
| .05 | 3.82 | 3.46 |
| .01 | 5.06 | 4.59 |

Table 10. Cinerarias - Analysis of Scores and Dry Weights

| Source of Variation | Degrees of Freedom | Mean Square Score | Mean Square Dry Weight |
|---|---|---|---|
| Soils | 6 | 146.21 | 394.08 |
| Replications | 14 | 32.78 | 38.43 |
| Error | 81 | 27.68 | 22.77 |

The test of significance of differences in scores and dry weight, respectively:

$$F = 146.21/27.68 = 5.28$$
$$F = 394.08/22.77 = 17.31$$

of this crop were highly significant and without question were of sufficient magnitude to be of commercial importance.

The cinerarias bloomed between March 21 and April 23. Plants were removed once weekly for scoring. Due to the limited number of plants per treatment, significance could not be attributed to a slight difference in the time of bloom of the plants on the different soils, for there was so much overlapping. It seemed, however, that the compost, Webster and O'Neill were somewhat earlier than the others.

Those plants which were not ready until late April were injured somewhat by the intense sunlight and heat already prevailing. In growing this crop it is recommended that it be used only as a late winter or early spring crop. The time of flowering is easily controlled, since it depends largely on the time when the seed is sown.

From the small mean square for replications in the analysis of variance (table 10) it may be concluded that the bench positional effect only slightly reduced the sum of squares attributed to error. Rotating the blocks at frequent intervals was probably effective in cutting down the positional bench effects.

## Carnation

It has already been explained that a properly designed experiment could not be established with the carnations because of an insufficient number of plants. The injury resulting from nematode infestation also reduced the set-up considerably. Furthermore, moving large plants with a considerable volume of field soil about their roots introduced a confounding factor. In the future the plants should be grown on the respective soils at least after the $2\frac{1}{2}$-inch pot stage.

For the several reasons given above, too much significance cannot be attributed to any of the results with this crop. Certain things may, however, be pointed out. Data on carnation varieties Chief Kokomo and King Cardinal are presented in tables 11 and 13 respectively; the analyses of variance are in tables 12 and 14. Because records were kept only on variety Chief Kokomo until March 1, the average production per plant was much lower on that variety. Accounting for the shorter stems are varietal differences and the fact that during the early period of production stem length is less. King Cardinal was allowed to produce during the spring. Heavy production, together with long stems during that period, increased the stem length average.

Quite significant, in view of the results secured with the crops previously discussed, is the small number of flowers per plant on the Clinton soil. Clinton gave the lowest yield with both varieties.

If the differences in average flower production and flower diameter of var. Chief Kokomo are really significant, it may be due to that variety being less tolerant of a range of soils.

Splitting of carnation calyces has been discussed as a

Table 11. Carnation var. Chief Kokomo - Average Number of Flowers, Flower Diameter and Stem Length

| Soil | Average Number of Flowers | Average Flower Diameter (inches) | Average Stem Length (inches) |
|---|---|---|---|
| Wabash | 7.5 | 2.90 | 13.7 |
| O'Neill | 7.3 | 2.70 | 13.9 |
| Compost | 6.2 | 2.73 | 12.0 |
| Knox | 5.3 | 2.75 | 13.4 |
| Clarion | 5.2 | 2.55 | 12.6 |
| Webster | 4.8 | 2.70 | 13.1 |
| Clinton | 4.5 | 2.78 | 14.2 |

Table 12. Carnation var. Chief Kokomo - Analysis of Variance of Number of Flowers, Flower Diameter and Stem Length

| Source of Variation | Degrees of Freedom | Mean Square | | |
|---|---|---|---|---|
| | | No. of Flowers | Flower Diam. | Stem Length |
| Soils | 6 | 38.6 | 407.5 | 366.8 |
| Error | 35 | 9.0 | 105.6 | 378.7 |

The tests of significance of differences in:

Number of flowers: $F = 38.6/9.0 = 4.29$
Flower diameter: $F = 407.5/105.6 = 3.86$
Stem length: $F = 366.8/378.7 = .97$

Table 13. Carnation var. King Cardinal - Average Number of Flowers, Flower Diameter and Stem Length

| Soil | Average Number of Flowers | Average Flower Diameter (inches) | Average Stem Length (inches) |
|---|---|---|---|
| Knox | 13.2 | 2.89 | 18.3 |
| Webster | 13.2 | 2.88 | 19.4 |
| Clarion | 12.8 | 2.86 | 19.7 |
| O'Neill | 12.5 | 2.90 | 20.6 |
| Wabash | 12.0 | 2.94 | 19.5 |
| Compost | 10.8 | 2.90 | 19.2 |
| Clinton | 9.2 | 2.99 | 16.7 |

Table 14. Carnation var. King Cardinal - Analysis of Variance of Number of Flowers, Flower Diameter and Stem Length

| Source of Variation | Degrees of Freedom | Mean Square | | |
|---|---|---|---|---|
| | | No. of Flowers | Flower Diam. | Stem Length |
| Soils | 6 | 13.0 | 69.7 | 903.3 |
| Error | 35 | 5.8 | 64.9 | 525.1 |

The tests of significance of differences in:

Number of flowers: $F = 13.0/5.8 = 2.24$
Flower diameter: $F = 69.7/64.9 = 1.07$
Stem length: $F = 903.3/525.1 = 1.72$

rather serious yet common abnormality. Records on these two varieties showed no splits for var. King Cardinal and 9.4% splits for var. Chief Kokomo. This must certainly be a varietal difference.

## Soils

In deciding whether lime should be applied to any of the soils, the reaction preferences of the crops and the soil reactions were considered.

Laurie (22) found that snapdragons in soils at pH 4.4, 5.0, 5.9, 7.2 and 8.2 grew best in the range of pH 5 to 6. At pH 4.4 and 8.2 the plants became chlorotic and growth was reduced.

Stocks do best on soil with a neutral reaction (24), while cinerarias do best in a slightly acid soil, pH 6-7 (26).

The reaction preference of the carnation has received more attention than those of the other crops. Wiggin (54), maintaining a soil at pH values between 5.5 and 8.5, found that carnations produced the greatest number of flowers and best stems at pH 6.5, although there was actually little advantage for any one treatment. Weinard and Decker (50), working with a soil maintained at pH 5 to 5.5 and at 7.0 to 7.5, found no consistent differences in the number of flowers produced by the different varieties on limed as compared with acidified soil. The stems appeared to be slightly stronger on the limed plots.

Since none of the soils were extreme in their reactions and the crops, from the literature, do not appear to be exacting in their needs, no additions of lime or other corrective materials were made.

The original and final pH values of the soils were as follows:

| Soil | Original pH | Final pH |
|---|---|---|
| Compost | 7.0 | 7.5 |
| Knox | 6.9 | 7.2 |
| Wabash | 6.6 | 7.0 |
| Clinton | 6.6 | 6.8 |
| Webster | 5.8 | 6.2 |
| O'Neill | 5.8 | 6.5 |
| Clarion | 5.2 | 5.9 |

At the end of the year the soils which had grown the snapdragons and stocks were tested and they all showed a rise in pH (see above). This can probably be attributed primarily to the effect of hard water, for college water was used throughout the course of the experiment. Burk (10) has shown such effects from the use of campus water.

Total nitrogen determinations on the soils were as follows:

| Soil | Per cent Nitrogen |
|---|---|
| Compost | .47 |
| Knox | .32 |
| Webster | .30 |
| O'Neill | .29 |
| Wabash | .27 |
| Clarion | .20 |
| Clinton | .15 |

The percentages of nitrogen reported above are averages of three determinations. All are in line with the amounts expected for the several types except the Knox, which is known generally to be much lower. An explanation for this inconsistency may be the fact that the soil was taken from an area still bearing a natural stand of timber, with a considerable amount of litter and organic matter accumulated on the surface.

Interpreting the values of these soils for greenhouse use on the basis of the response of the four crops studied is not entirely possible. A great many inconsistencies among the crops are to be noted, for, as has been mentioned already, the response of plants depends on both the soil and the individual species.

One thing stands out rather plainly, that is, that the Clinton soil did poorly in all cases. There is little doubt but that this soil in its field condition is unsuitable for greenhouse work. Not only did it give poor growth, but it was most difficult to work with, for it dried and cracked badly and was often hard to water properly.

The inconsistent results with the compost have been noted already. Due to the additions of large amounts of organic matter it was in a good physical condition and could be worked easily. With cinerarias the compost gave by far the best results; with snapdragons stem length was shortest on that soil. Cinerarias are known to be gross feeders and require a large amount of fertilizer, especially nitrogen (28); on the other hand, snapdragons are probably more easily injured by high soluble salt concentrations.

The fact that many of the soils performed so nearly alike with the cinerarias, that the differences with the snapdragons were not of such magnitude as to be of great commercial significance, and that all of the stocks were of good commercial quality would lead to the assumption that nearly all of these soils with proper handling could be made to produce good flower crops. It must of course be realized that the soils are all among the more productive ones of the state. If some of the poorer types had been included, greater differences would undoubtedly have been found.

## SUMMARY

This paper constitutes the initial report on Iowa Agricultural Experiment Station Project No. 675.

The first year's work dealt with an investigation of the growth of snapdragons, stocks, cinerarias and carnations on six Iowa soil types and a greenhouse compost included as a standard.

Each of the soil types is representative of a soil being used by florists in an important greenhouse area of Iowa. The soils were brought to Ames in August, 1939, in two-cubic-yard quantities.

Preparatory to the planting of a crop, a uniform application of fertilizer (ammonium sulfate, muriate of potash and superphosphate) was made. Supplementary fertilization, based on crop response and soil nitrate tests, consisted of additions of ammonium sulfate in solution.

All of the crops were handled according to commercial practice as regards propagation, transplanting, temperature, watering, pinching and staking.

Snapdragons var. Cheviot Maid Supreme were grown in bench plots in randomized blocks with three replications. Individual plant records were kept on the number of flower spikes, stem length and the date of cutting. Illuminating gas, escaping into the greenhouse from a broken main, made it impossible to

get any measure of flower quality. Gas injury symptoms of snapdragons and stocks are described and illustrated. An interesting regression in stem length and time of bloom along a greenhouse temperature gradient was noted.

Non-branching stocks var. Lilac Lavender were grown during the spring as a bench crop following the snapdragons. Records consisted of a count of the total number of "flowers plus buds" and the total height of the plants at the time of cutting. There are also photographs of the crop.

As a representative of flowering potted plants, cinerarias were included. They were finished in 5½-inch pots. In the experimental design randomized blocks with 15 replications were employed with one pot of each soil per block. To reduce bench effects, the blocks were rotated fortnightly. Dry weight of tops and an average score determined by three independent judges from a modified score card were the two criteria of performance.

Carnations were included for the purpose of giving some preliminary information. Three varieties were used. Records consisted of flower production and flower stem length and flower diameter. Root nematode infestation reduced the significance of this phase of the work.

## CONCLUSIONS

1. Snapdragons showed highly significant differences among their mean stem length on the different soils. Commercially the differences are probably not of great importance. The number of flower spikes per plant did not appear to be influenced by soil.

2. Stocks grew uniformly and well on all the soils. Differences in plant height and total number of "flowers plus buds" were not significant.

3. Cinerarias in pots showed differences in their response to the several soils; however, the differences between all soils were not significant. Differences here are of commercial importance. Plants on the compost were far superior to those on any other soil.

4. The carnations gave little information to which any significance can be attributed.

5. Clinton silt loam gave quite consistently the poorest results. This poor performance, coupled with a physical condition which makes it difficult to work, makes it undesirable as a greenhouse soil. That the other soil types differ significantly in general crop response cannot be stated.

6. A temperature gradient which existed in the greenhouse in which the snapdragons and stocks were grown is believed to be the cause of an interesting regression in the growth of

these two crops. Snapdragons at the warm end of the house bloomed earlier and had shorter stems than those at the cooler end. Stocks growing at the warm end of the bench had fewer flower buds.

7. Measuring the response of cinerarias by dry weight of tops or by the average number of points computed from the scoring by three independent judges gave essentially the same results. Scoring has many advantages in that it is easier and permits the plants to be sold.

8. 9.4 per cent of the flowers of carnation var. Chief Kokomo had split calyces; none of the flowers of var. King Cardinal were "splits." This difference is undoubtedly due to genetical factors.

9. Rotating the cineraria blocks every two weeks was effective in reducing positional bench effects.

10. Significant positional bench effects were noted with the snapdragons. This serves in establishing the need for properly replicated experiments in greenhouse research.

11. Cinerarias blooming late in the spring were poor in quality in contrast to those flowering earlier. This is thought to be due to high temperature and high light intensity prevailing at that season. It is suggested that this crop be grown primarily for late winter and early spring sales.

12. Data on single and double stocks showed only slight differences in their time of bloom, their height, and their average number of flower buds.

## SUGGESTIONS FOR FURTHER WORK

It has already been suggested that all of the soils can probably be used successfully in greenhouse flower production if they are properly handled. The addition of some type of organic matter might be a method of improving their physical condition. It is suggested that this be tried.

Having a number of different soil types available can be of great advantage in testing fertilizer recommendations and other methods of soil treatment and handling before disseminating such information. A serious objection to much soil research with flower crops has been that only one soil was used.

Some studies have been concluded on soil reaction preferences of flower crops (50, 54) and on effective nutrient levels for forced plant growth (40, 48, 49). However, the information is still meager. With several soils available the general applicability of this work could be determined.

Effective moisture levels are also coming in for study (33, 56), but again the work is being done using only one soil, whereas if several were used it would be of greater value.

That soil temperature may have a profound influence on plant growth has been shown (5, 20). Further studies in that field may reveal many facts of practical significance. With more than one soil available, interactions of temperature effects and soil type may be investigated.

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